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Evaluation of Shrinkage, Mass Changes and Fracture Properties of Fine-aggregate Cement-based Composites during Ageing

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Abstract

The paper deals with the experimental determination of relative length changes development during cement based composite ageing. Special moulds with the dimensions 100 × 60 × 1000 mm were used for the measurements. These moulds were filled and placed on an advanced weighing table that enables continuous recording of mass losses caused by free drying of the specimen surface. In this way, the mass losses and changes in the length of the cement composite in the moulds were measured simultaneously. The shrinkage moulds were modified in order to measure also the long-term relative deformation of fine-aggregate concrete specimens as a result of drying. The outputs of the measurement are given in the form of the diagrams displaying the relationship between the relative length changes or the mass losses and the time of cement composites ageing. Besides the measurement of length changes, three-point bending fracture tests at the age of 3 and 28 days were also performed. The modulus elasticity, effective fracture toughness and specific fracture energy values were determined from load versus deflection diagrams recorded during fracture experiments on the specimens with dimensions 40 × 40 × 160 mm.

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Keywords: cement composite; volume changes; shrinkage; mass loss; fracture test

1. Introduction

The determination of the detail development of volume changes of cement-based composites still remains in the focus of civil engineers and concrete producers. Along with the design of new materials, new factors influencing

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changes in volume appear throughout the whole time of their setting and hardening. Advancement in technology and composition of building materials in turn requires advancement in test procedures used for the determination of new materials' physical and mechanical parameters. The current approach in the field of material testing is aimed at identifying disruptions in the internal structure of structural elements as early as possible. This facilitates early diagnostics of the problem which allows for relevant precautions preventing later collapse of the building to be designed.

The reasons for the focus on this area are arising from the fact, that many problems with cement composites cracking are originated in the early ages [1,2,3]. Cracks formation and their propagations are for civil engineers closely associated with the tensile strength value, which is generally only 10 percent of compressive strength, and of course with the fracture parameter values. At early ages, the strength is still developing while stresses are generated by volume changes. Controlling the variables that affect volume change can minimize high stresses and cracking [2,4,5]. Experience gained from measurements performed in recent years suggests the necessity of assessing the magnitude of shrinkage in two consecutive stages of concrete ageing – in the early age and at later ages [5,6,7,8]. From measurements performed in the early-age cement-based composites, differences in the development of the volume changes can be identified, as well as differences in the initiation and propagation of cracks which cannot be identified with usual measurement started after removing the specimens from the moulds (typically after 24 hours) [9].

2. Experimental part

2.1. Materials

For purpose of experimental measurement, three fine-grained cement composites mixtures were designed and manufactured. They differed in the water to cement ratio (*w*/*c*) and in amount of plasticizer. A design of composition is based on the standard ČSN EN 196-1 [10]. The fresh composite was made with quartzite sand with the maximum nominal grain size of 2 mm standardized according to ČSN EN 196-1 [10], Portland cement type 42.5 R and water in ratio of 3:1:0.5 (S:C:W), 3:1:0.47 and 3:1:0.35 with addition of super-plasticizer SVC 4035 in amount of 1 % by cement mass. A mixing device with controllable mixing speed was used to prepare the fresh mixtures. Together 15 specimens were prepared from each mixture (see Fig. 1). The basic information about the composition, manufacturing and properties of the fresh composite are given in Table 1. The properties of the fresh composite were determined in accordance with ČSN EN 1015-3 [11] and ČSN EN 1015-6 [12].

Table 1. Composition and properties of fresh composites.

		Composite ID		
Components and properties	Units	0_04042016	III_02052016	IV_09052016
Sand	[kg]	45.9	45.9	45.9
Cement I 42.5 R	[kg]	15.3	15.3	15.3
Water	[kg]	7.65	7.16	5.35
Super-plasticizer SVC 4035	% by cement mass	–	–	1.0
w/*c* ratio	[–]	0.5	0.47	0.35
Mixing speed	[revolutions per minute]	20	30	40
Workability	[mm]	140.0	127.5	135.0
Bulk density	[kg/m^3]	2200	2210	2280